2009

Magnitude and Variability in Emissions Savings in the Corn-Ethanol Life Cycle from Feeding Co-Products to Livestock

Virgil R. Bremer
University of Nebraska - Lincoln, vbremer2@unl.edu

Adam Liska
University of Nebraska - Lincoln, aliska2@unl.edu

Terry J. Klopfenstein
University of Nebraska - Lincoln, tklopfenstein1@unl.edu

Galen E. Erickson
University of Nebraska - Lincoln, gerickson4@unl.edu

Haishun Yang
University of Nebraska-Lincoln, hyang2@unl.edu

See next page for additional authors

Magnitude and Variability in Emissions Savings in the Corn-Ethanol Life Cycle from Feeding Co-Products to Livestock

CRC Life Cycle Assessment Workshop, Chicago, Oct. 20-21, 2009

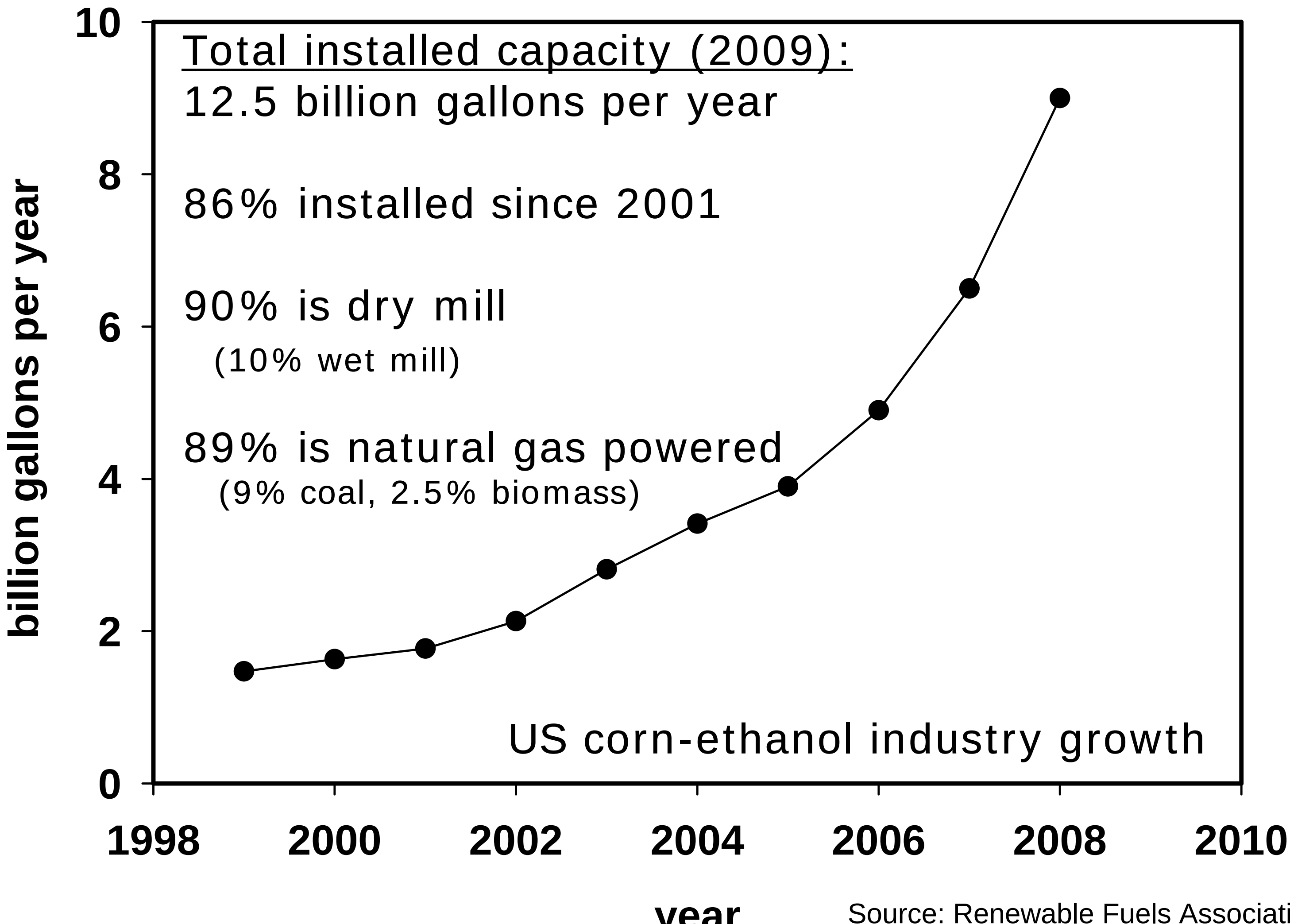
Virgil R. Bremer[1], Adam J. Liska[2*], Terry J. Klopfenstein[1], Galen E. Erickson[1], Haishun S. Yang[3], Daniel T. Walters[3], and Kenneth G. Cassman[3,4]

Department of Animal Science[1], Department of Biological Systems Engineering[2], Department of Agronomy and Horticulture[3], Nebraska Center for Energy Sciences Research[4], University of Nebraska-Lincoln

***aliska2@unl.edu, www.bess.unl.edu**

Production of biofuel co-products:

~90% of corn-ethanol biorefineries are currently natural gas powered dry mills producing distillers grains for livestock feed

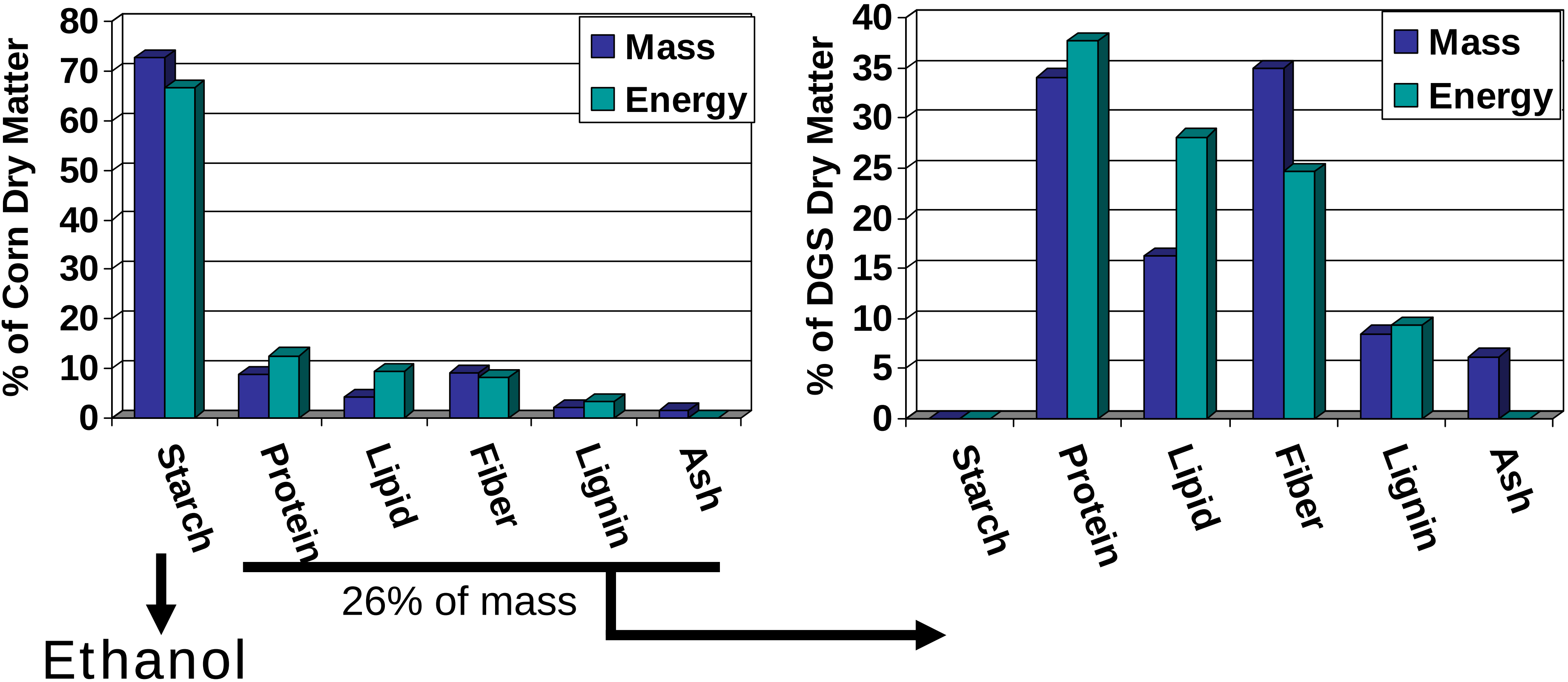


Source: Renewable Fuels Association, Jan. 2009

Mass and energy content of grain & co-products

Corn grain
17.4 MJ/kg

Co-products
22.6 MJ/kg



Source: Bremer et al. *Journal of Environmental Quality*, in press

Feeding co-products to Midwest livestock in 2006

Survey Data for US Corn Belt Livestock CP Feeding, 2006				
Livestock Classes:	Beef	Dairy	Swine	Total
Corn Belt Production*, million head	11.3	3.2	64.1	78.6
Fraction of US Livestock in Corn Belt*, %	50%	33%	70%	-
Fraction of Corn Belt Herd Fed Co-product‡, %	63%	49%	40%	-
Current DGS Feeding Practices in the Midwest 2006 (Roughly 33% of all US co-product produced)				
Dietary DGS inclusion Level**, % of dietary intake	20%	10%	9%	-
Total DGS use‡, million Mg (% inclusion x animals fed)	2.4	1.3	0.6	4.3
Distribution of DGS use‡, % of total	56%	30%	14%	100%
Ethanol Industry to Supply DGS‡, Billion L/year	3.4	1.9	0.9	6.2

*NASS (National Agricultural Statistics Service). 2007. Ethanol co-products used for livestock feed. Washington, D.C. **Bremer et al. *Journal of Environmental Quality*, in press, ‡calculated

Analysis of co-product (CP) GHG emissions credits for the life cycle of corn-ethanol

- Co-product GHG credits can represent 10 to 40% of total life cycle GHG emissions (Liska et al. 2009)
- Abundant CP has led to new feeding practices
- **Research presented here:** Updated CP credit for the BESS model for the corn-ethanol life cycle from <u>beef cattle only</u> to recent co-product feeding practices for <u>beef, swine, and dairy</u> livestock
- Performed meta-analysis and data summary for current beef, swine, and dairy feeding parameters:

1) dietary inclusion level for CP feeding (% diet)
2) efficiency of feeding different co-product types to different livestock (e.g. gain-to-feed ratios)
3) Displacement ratios of conventional feeds

(utilized new survey data for biorefinery efficiency)

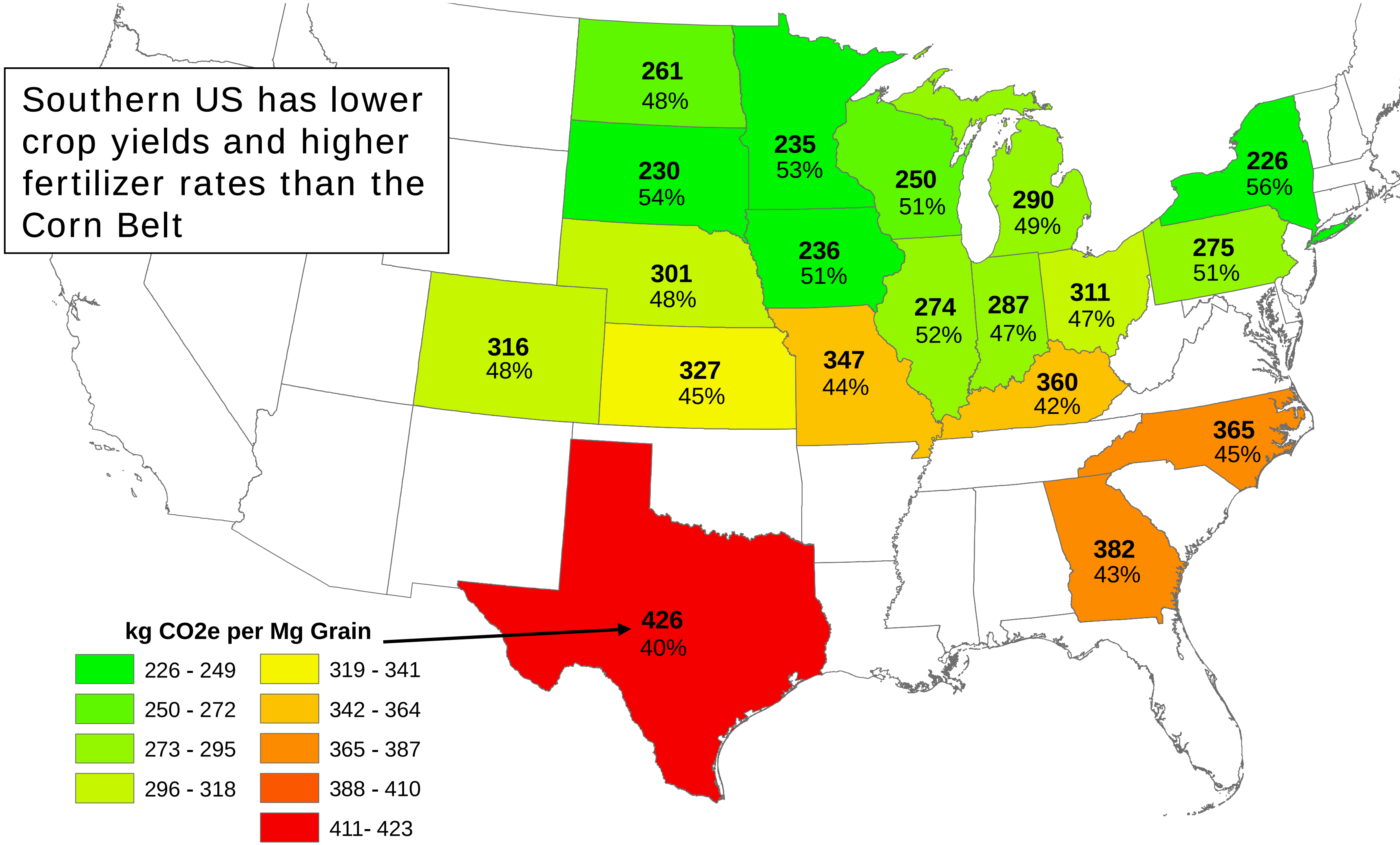
Source: Bremer et al. *Journal of Environmental Quality*, <u>in press</u>

Co-product types, livestock classes, and resulting dietary substitutions from updated BESS model

Region:	-	-	-	Midwest	Iowa	Nebraska	Texas
Co-product type produced & fed							
Dry distillers grains (dm), %	100	100	100	35	72	14	0
Modified distillers grains (dm), %	-	-	-	32.5	14	19	0
Wet distillers grains (dm). %	-	-	-	32.5	14	67	100
Beef cattle, %	-	-	100	56	18	74	97
Dairy cattle, %	-	100	-	30	10	2	3
Swine, %	100	-	-	14	72	24	0
Dietary substitutions, kg kg^{-1} co-product (dry matter)							
Corn	0.57	0.45	1.21	0.91	0.68	1.20	1.35
Soybean meal	0.43	0.55	0.0	0.23	0.36	0.07	0.02
Urea	0.0	0.0	0.064	0.036	0.012	0.055	0.064
Total	1.00	1.00	1.27	1.17	1.06	1.33	1.43

Source: Bremer et al. *Journal of Environmental Quality*, in press

Regional variability in corn production GHG-intensity is also relevant for corn substitutions in the CP credit (e.g. larger credit in Texas)



Source: Liska et al, *Journal of Industrial Ecology*, 13, 58-74 (2009)

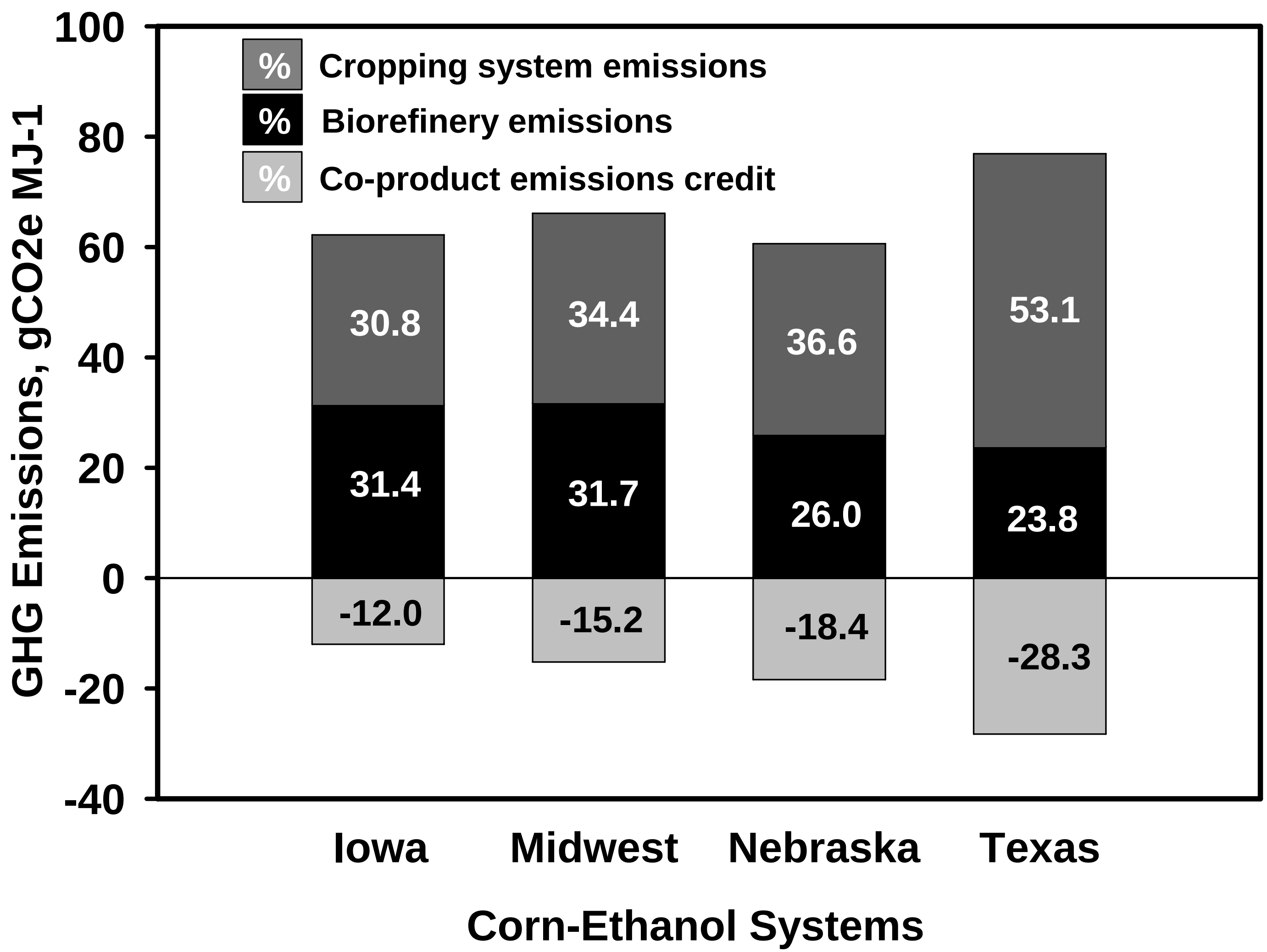
Components of BESS model GHG emissions credit and life cycle impacts based on above dietary substitutions

Regions	Midwest	Iowa	Nebraska	Texas
GHG emissions credit, $gCO_2e\ MJ^{-1}$				
Corn (regional sources)	9.64	6.50	12.8	22.1
Soybean meal	2.82	4.56	0.91	0.21
Urea	1.60	0.52	2.43	2.85
Diesel fuel	-0.10	-0.04	-0.21	-0.26
Enteric fermentation	1.27	0.424	2.52	3.42
Total	15.2	12.0	18.4	28.3
Biorefinery thermal energy* $MJ\ L^{-1}$	7.72	7.60	5.70	4.91
Net ethanol Intensity, $gCO_2e\ MJ^{-1}$	52.3	51.6	43.7	50.0
GHG Reduction relative to gasoline, %	46.5%	47.2%	55.3%	48.8%

*A equation was developed between co-product types produced (% wet, modified, and dried) and energy use for drying based on biorefinery survey data

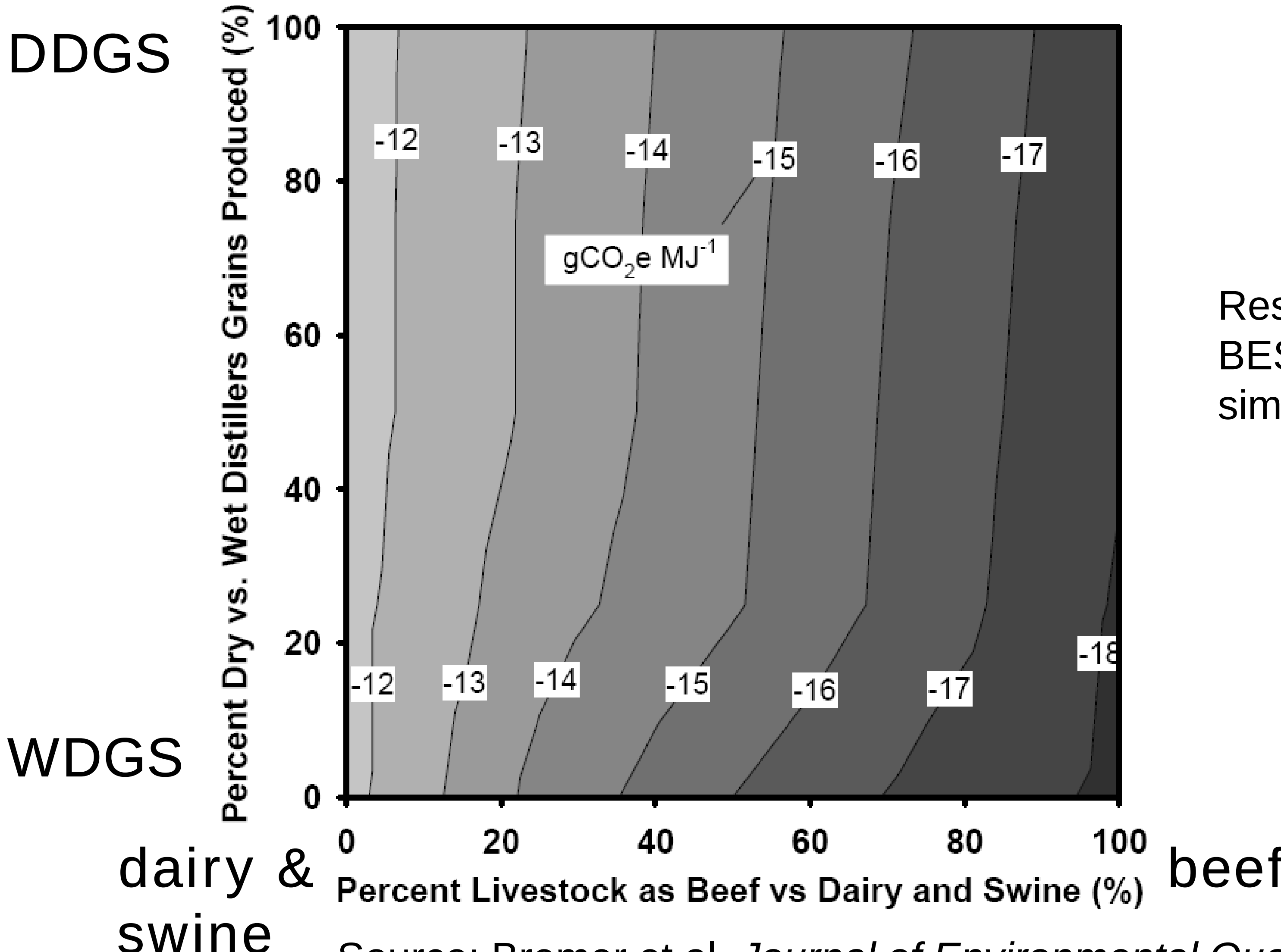
Source: Bremer et al. *Journal of Environmental Quality*, in press

GHG emissions credits and life cycle impacts



Source: Bremer et al. *Journal of Environmental Quality*, in press

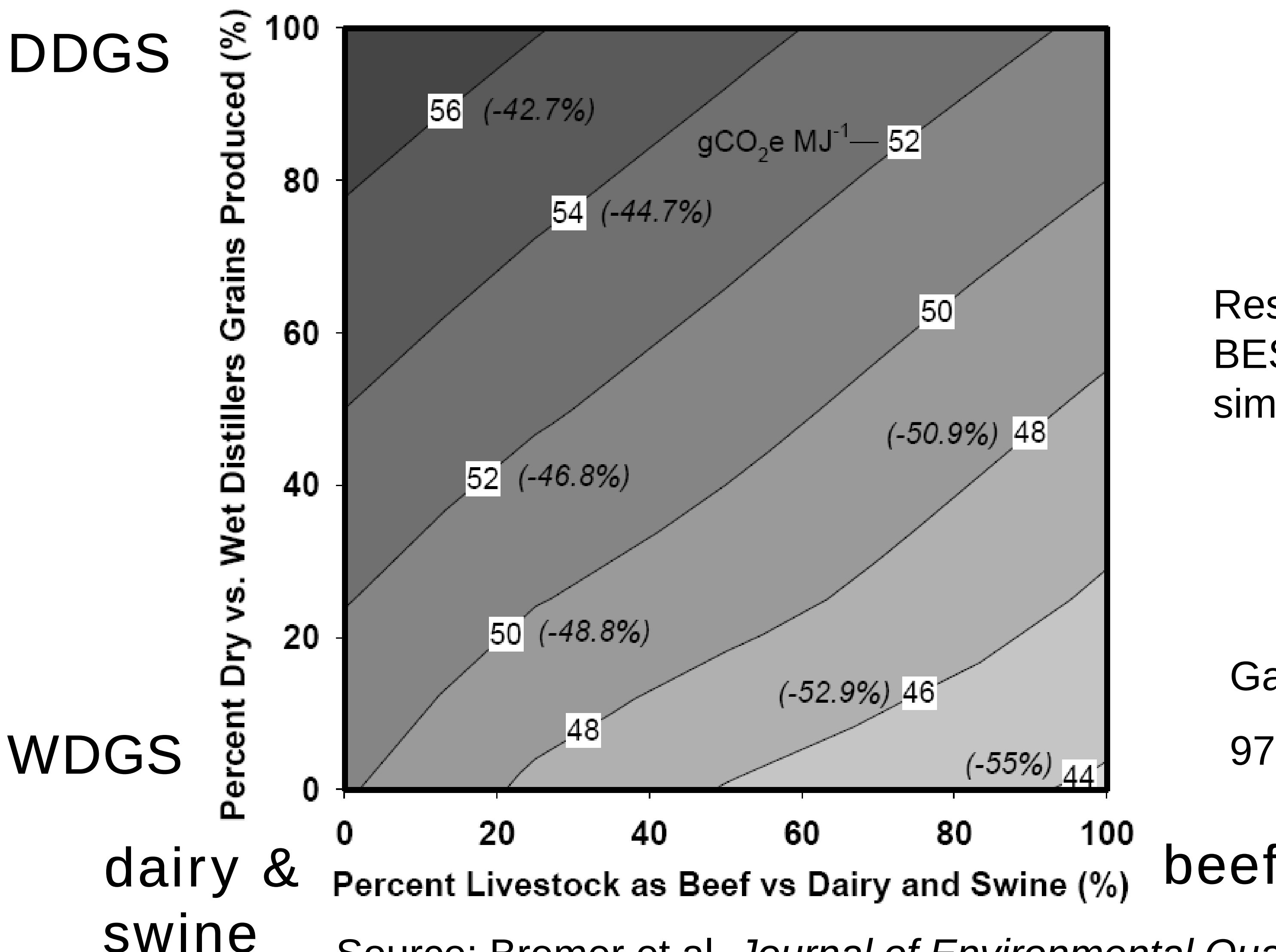
Variability in co-product GHG emissions credits for individual biorefineries/regions depending on type of CP produced and livestock class fed



Results of BESS model simulations

Source: Bremer et al. *Journal of Environmental Quality*, in press

Life cycle GHG emissions intensity and % reductions for corn-ethanol compared to gasoline, depending on co-product variability & energy savings for drying CP



Results of BESS model simulations

Gasoline:

97.7 gCO_2e/MJ

Source: Bremer et al. *Journal of Environmental Quality*, in press

Recommendations: Data needed for improvements and reduction in uncertainty

1) Types and characteristics of co-products produced at corn-ethanol biorefineries in the U.S.
2) Types of livestock being fed co-products in the entire U.S.
3) Inclusion level of co-products in livestock diets
4) Hauling distances between co-product production and use
5) Amount of co-product exported
6) Differential N_2O emissions during co-product feeding need to be better understood (IPCC does not capture regional variability)
7) Emission factors in the life cycle of biofuels need to be standardized to determine a consensus co-product credit value (more intense upstream emissions will increase co-product value)

Conclusions

- Co-product GHG emissions credit varied by >2-fold, from 11.5 to 28.3 gCO_2e per MJ of ethanol produced
- Co-product GHG emissions credit depend on

  -types of co-products produced

  -proportion fed to beef cattle vs. diary or swine

  -location of corn production; the CP credit is highest in regions where GHG kg^{-1} grain are highest
- Depending on CP production types and feeding livestock classes, corn-ethanol net life cycle GHG intensity is 44-56 gCO_2e per MJ
- Midwest corn-ethanol reduces GHG emissions compared to gasoline by 47% on average, with co-products offsetting 23% of positive emissions

  (Bremer et al. 2009; Liska and Cassman 2009)

Funding support

- USDA NC506 Regional Research
- Western Governor’s Association
- US Department of Energy
- University of Nebraska Center for Energy Sciences Research
- Environmental Defense

- **FREE download of BESS model: www.bess.unl.edu**

References

- Bremer V.R., A.J. Liska, T.J. Klopfenstein, G.E. Erickson, H.S. Yang, D.T. Walters, K.G. Cassman, **Emissions Savings in the Corn-Ethanol Life Cycle from Feeding Co-Products to Livestock**, *Journal of Environmental Quality*, in press
- Liska A.J., H.S. Yang, V.R. Bremer, T.J. Klopfenstein, D.T. Walters, G.E. Erickson, K.G. Cassman, **Improvements in Life Cycle Energy Efficiency and Greenhouse Gas Emissions of Corn-Ethanol,** *Journal of Industrial Ecology,* 13, 58-74 (2009)
- Liska A. J., and K.G. Cassman, **Response to Plevin: Implications for Life Cycle Emissions Regulations**, *Journal of Industrial Ecology,* 13:508-513 (2009)
- Klopfenstein, T., G. Erickson, V. Bremer. **Use of Distillers Byproducts in the Beef Cattle Feeding Industry**. *Journal of Animal Science, 86*, 1223-1231 (2008)
- Liska A.J. , and R.K. Perrin, **Indirect Land Use Emissions in the Life Cycle of Biofuels: Regulations vs. Science***, Biofuels, Bioproducts, & Biorefining,* 3, 318-328 (2009)
- Liska A. J., and K.G. Cassman, **Towards Standardization of Life-Cycle Metrics for Biofuels: Greenhouse Gas Emissions Mitigation and Net Energy Yield**, *Journal of Biobased Materials and Bioenergy* 2, 187-203 (2008)
- Perrin R.K., Fretes N., Sesmero J.P. **Efficiency in Midwest US Corn Ethanol Plants: A Plant Survey**, *Energy Policy*, 37, 1309-1316 (2009)